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CHALLENGES IN LCA-BASED DECISION MAKING INVOLVING HEAVY METALS LONG-TERM EMISSIONS FROM LANDFILLS

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Life Cycle Assessment (LCA) is a decision support tool related to the quantification of environmental impacts of products and systems. LCA is widely used in waste management in order to support decisions regarding the environmental performance of different technologies or integrated waste management systems.
When decisions supported by LCA involve landfilling, the life cycle impact assessment of landfill processes suffers from the lack of an adequate methodology for assessing long-term toxic impacts caused by the release of heavy metals into the soil compartment. The life cycle assessment methodology is based on time integration, which poses no problems on handling emissions occurring over a short time period. However, heavy metals leach out of landfills for a period of several thousands of years. This situation poses a substantial barrier in the justification of decisions taken on the basis of the sustainability performance of waste management systems.
Current practice with respect to the handling of heavy metals emissions from landfills follows one of two approaches: 1) either the time integration principle is applied and all emissions are taken into account, or 2) emissions occurring beyond a time limit (usually set to 100 years) are cut off. In the first case, toxic impacts will likely dominate the impact assessment and in the latter, a large part of the heavy metals emissions is neglected as more than 95% of all heavy metals are likely to remain in the landfill during the first 100 years. Theoretical but not yet widely applied approaches have also been proposed. One attempt relies on the use of economic discounting principles to account for impacts from future heavy metals emissions, but utilises a subjectively defined discount rate. Another effort defines a separate impact category to treat emissions occurring after 100 years, but it lacks further interpretation and requires weighting relative to emissions and impacts occurring sooner.
One of the main barriers for the development of an appropriate methodology is the difficulty of predicting the evolution of the mass or concentration of heavy metals leaching out of the landfill, during the several millennia that their release takes place. An appropriate emission profile, customised for the main heavy metals would reveal whether the emissions follow a stable pattern or not and also their proximity to the present.
Although the mechanisms governing the kinetics of heavy metals are known and well-investigated, the prediction of their release from landfills faces the challenge of identifying which of the influencing parameters will dominate. Moreover, field or test measurements cannot validate the existing models, as such long time spans are impossible to simulate in the laboratory.
A literature review revealed three models, one laboratory experiment and one computer programme simulation, aiming at predicting heavy metals release in a time scale larger than or equal to 10,000 years. These five studies investigate different types of waste, a diverse number of heavy metals and waste types.
The first model is based on the intrusion of oxygen into a generic waste type landfill, which determines the depletion of the contained organic matter, responsible for the retention of heavy metals and aims at estimating the time span when all metals bound to organic matter will have been released. The second model assumes a dependence of selected heavy metals (Cd, Ni, Pb, Zn and V) leaching on pH, establishes the function of heavy metals' leaching concentrations, and attempts predictions of pH evolution in a landfill up to 100,000-250,000 years. The third model is taking into account the soil infiltration rate,

share of macropore flow and sorption capacity of the waste to model long-term leaching behaviour of Cd and Cu in municipal solid waste incineration residue landfills.

The laboratory test used a column percolation experiment on samples from a municipal solid waste incineration air pollution control residues landfill, up until the liquid-to-solid ratio reached 200-250 l/kg (corresponding to more than 10,000 years), in order to determine the leaching behaviour of a large variety of heavy metals. The software simulation used a geochemical landfill model to predict the depletion of, among others, heavy metals from a typical municipal solid waste landfill over a 20,000-year period.

The comparison and juxtaposition of the five studies gives insight into the different approaches and influencing factors for the heavy metal release from landfills and provides different emission profiles. Not all studies produce emission profiles, but these are deducted from the estimations already included in the studies. The emission profiles create a range of possible outcomes from landfilling of different types of waste depending on different parameters taken into account. An emission profile can then be produced for all major heavy metals.

The heavy metals' emission profiles are then directly incorporated into a time-dependent life cycle inventory (LCI). By means of USEtox^{TM}, an environmental model for characterization of human and ecotoxic impacts, the toxic impacts from the combined release of four heavy metals (Cd, Cu, Ni and Pb) from a specific landfill are estimated as a function of time.

The interpretation of these time-dependent impacts contributes to an assessment of the importance of future heavy metal emissions from landfills if current conditions are assumed constant. These results also contribute to a more informed decision-making process referring to a sustainability assessment of waste management systems that include landfills.